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Physical Model Study of Scour at Ventura Harbor, California

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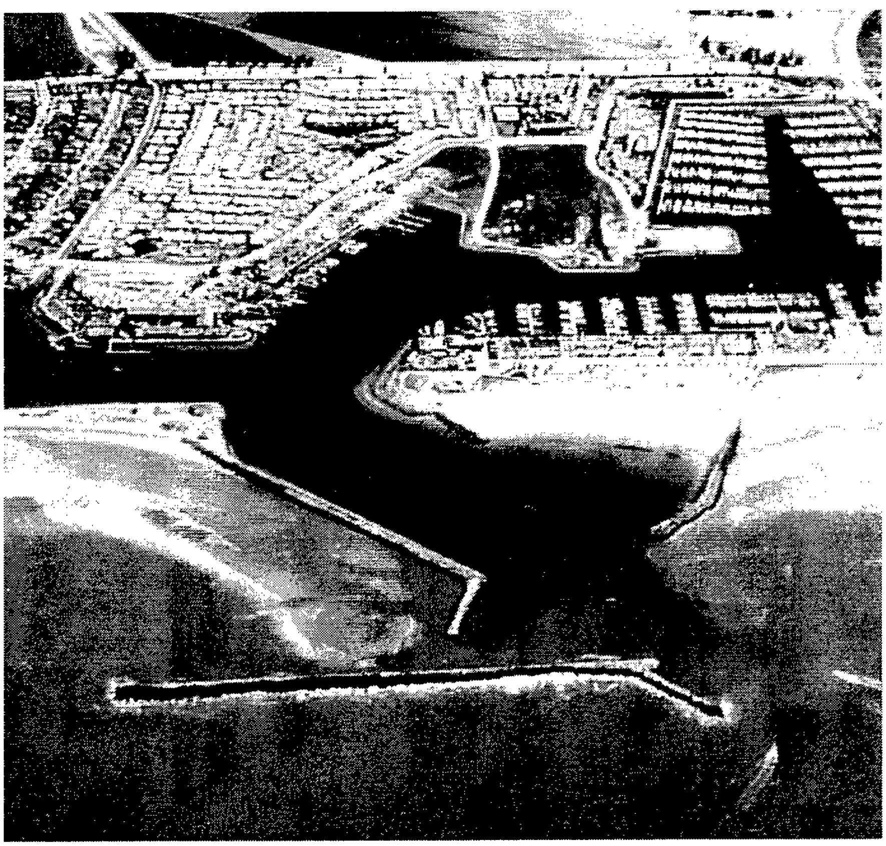

Figure 1. Aerial view of Ventura Harbor, Ventura, California

This article describes a movable-bed physical model study of scour that occurred on the leeside of the detached breakwater at Ventura Harbor, California. The current-induced scour was an unanticipated result of structural modifications that reduced problematic shoaling of the main navigation channel. The laboratory physical model was used to predict future scour potential and to optimize the design of remedial toe protection intended to prevent leeside armor layer damage on the detached breakwater.

The study was conceived as a Master of Engineering research project during Mr. Schwichtenberg's participation in the *Coastal Engineering Education Program*, a cooperative program conducted by Texas A&M University and the U.S. Army Engineer Waterways Experiment Station (WES).

Ventura Harbor

Ventura Harbor is a man-made commercial and recreational harbor located on the southern California coast approximately 100 km northwest of Los Angeles, California (Figure 1). The harbor has approximately 200 commercial berths and 1,600 recreational berths, and it provides ocean access to an attached private marina with 300 boat slips. The principal structural features of the present-day harbor entrance are two rubble-mound jetties, a beach groin to the south of the entrance,

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and a detached rubble-mound breakwater as shown in Figure 2.

Since its original construction by local interests in 1963, the Federally maintained entrance to Ventura Harbor has undergone a series of engineering modifications in an effort to decrease deposition of littoral sediments in the navigation channel. Construction in 1972 of the detached breakwater with a large sand trap in the lee eased the shoaling problem somewhat, but some sand still escaped the sand trap and entered the navigation channel.

In 1994 a spur groin was added to the tip of the north Ventura Harbor jetty, narrowing the gap between the north jetty and detached breakwater (see Figure 2). This modification appeared to promote increased trapping of sediment during normal weather conditions; but as is often the case, solving one problem created a new, unforeseen difficulty.

Ventura Harbor Scour Problem

A few months after completion of the spur groin, harsh winter storms impacted the project. This resulted in the formation of a 9-m-deep scour hole in the gap between the north jetty spur groin and detached breakwater (bottom sketch of Figure 4). In addition, structural damage occurred along 46 lineal meters of the detached breakwater leeside armor south of the spur groin, and there was significant channel shoaling. The principal cause of breakwater damage was scour of the breakwater toe and subsequent slumping of the armor layer. It appears that storm-generated, southward-flowing longshore currents accelerated through the narrow gap in a manner similar to a jet, and the high velocities created the large scour hole.

Emergency repairs were undertaken by the Los Angeles District of the Corps of Engineers. These repairs included dredging, infilling of the scour hole, construction of a rock sill along the gap between the north jetty spur and detached breakwater, and reconstruction of 61 lineal meters of the damaged breakwater. The sill had an elevation of -4.5 m MLLW and its placement is shown on Figure 3. In addition, remedial toe protection work was performed on the detached breakwater toe south of the sill. Repairs were completed by May 1995. However, there was concern that additional scour along the detached breakwater toe might occur during storm conditions in the region south of the sill as indicated on Figure 3. Such scour could undermine the toe and cause damage to the leeside armor, leading to costly repairs.

Due to the uncertainty of the scour potential, the Los Angeles District of the Corps of Engineers planned toe protection for regions of the breakwater scheduled for repair in 1996-97. This design was evaluated and refined in laboratory studies conducted at the Waterways

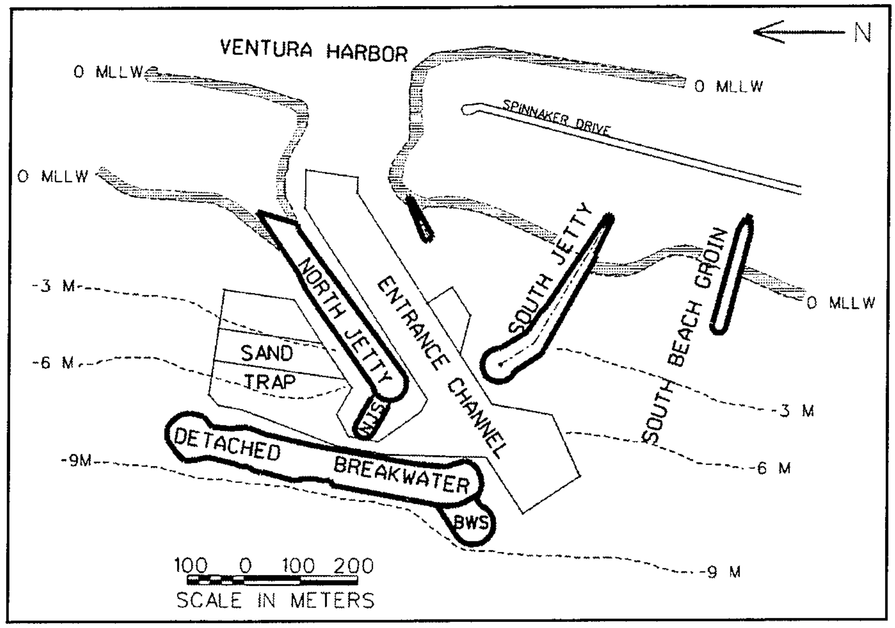

Figure 2. Ventura Harbor entrance planview

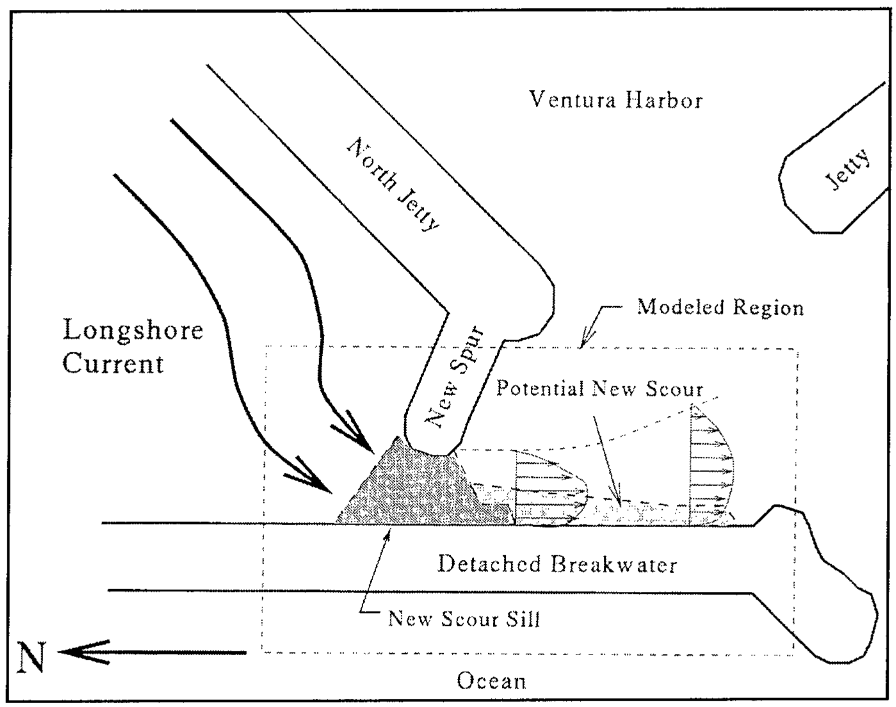

Figure 3. Scour sill and potential scour regions

Experiment Station during April-June, 1997.

Laboratory Physical Model Study

A movable-bed physical model study of Ventura Harbor scour was conducted with two primary objectives. The first was to determine if flow conditions similar to the flow that caused the original scour hole would cause additional scour downstream of the rock sill, thus endangering the detached breakwater leeside armor. The outcome of this analysis would support the decision on whether or not to fund construction of a protective toe berm along the leeside toe of the detached breakwater. The second objective was to evaluate and refine the 1996 provisional toe berm design (if it was determined that a toe berm would be needed to protect the leeside armor layer from undermining).

The region of Ventura Harbor entrance shown by the dashed line on Figure 3 was constructed over a movable-bed section in a large wave facility operated by WES's Coastal and Hydraulics Laboratory. The model was constructed at a model-to-prototype length scale of 1:25. Flows representing longshore currents were generated by pumping water through a current manifold.

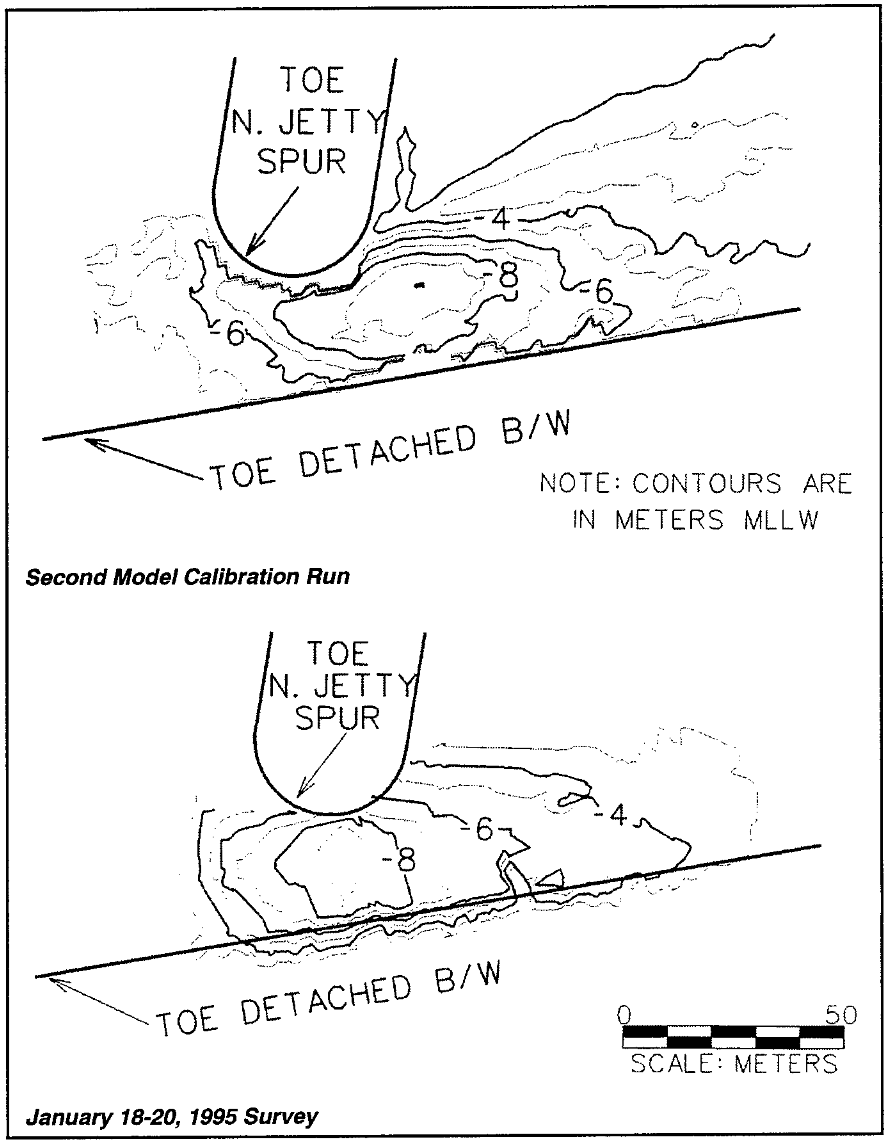

Figure 4. Model (upper) and Prototype (lower) Scour Hole Contours

Scour Model Calibration

The main difficulty with movable-bed models is obtaining correct similitude between the prototype and model sediments. In the case of Ventura Harbor, model similarity by strict similitude considerations for either bedload or suspended sediment transport was impossible. Therefore, the only way to obtain reasonable model similarity was through calibration of the model currents by model reproduction of the large scour hole that occurred along the gap between the north jetty spur and detached breakwater at Ventura Harbor. Model reproduction of the scour hole would also resolve the problem of not knowing the magnitude of flow discharge through the gap. Once the model was calibrated, the same model discharge could be used with reasonable confidence to simulate scour that could occur downstream of the sill under the same hydrodynamic conditions.

During calibration, currents were gradually increased until the sand bed between the north jetty spur and detached breakwater began to erode. Flow was kept steady until the scour hole appeared to have reached an equilibrium depth. If the maximum depth was not at the model equivalent of the maximum scour depth measured in the prototype, the flow rate was increased. Eventually, the equilibrium scour depth and general planform of the model scour approximately matched the prototype, as indicated by Figure 4.

The maximum flow velocity through the gap during calibration corresponded to a prototype equivalent of 2.9 m/s, which was very reasonable and fell within the range of previous onsite visual estimates for storm conditions.

Scour Downstream of the Rock Sill

The rock sill spanning the gap between the north jetty spur and detached breakwater at Ventura was constructed to scale in the physical model with the crest

elevation corresponding to a prototype depth of -4.5 m MLLW. This configuration represented the existing condition at Ventura, and the investigation was conducted to determine the likelihood of scour developing downstream of the rock sill under conditions similar to what caused the original scour hole.

Scour contours measured in the model downstream of the rock sill are shown in Figure 5. Contour values correspond to prototype depths in meters. The scour hole was deeper than the scour that occurred in the second calibration analysis, as shown in the upper portion of Figure 4. Besides being displaced downstream of the sill, the scour hole was narrower and more elongated than scour that occurred without the rock sill in place. Where the scour hole impinged on the breakwater toe, armor stones became unstable and fell into the scour hole.

The model study of the existing Ventura configuration strongly supported the hypothesis that current-induced scour at Ventura Harbor had the potential to undermine the leeside armor slope along the length of the detached breakwater south of the rock sill. This would cause considerable damage to the leeside armor slope requiring expensive repair. Therefore, construction of a protective toe berm along the detached breakwater is warranted.

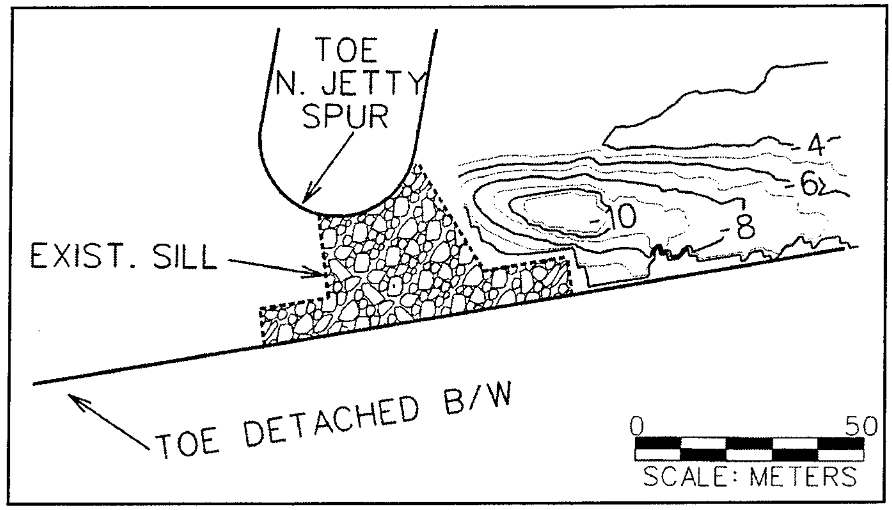

Figure 5. Ventura model scour downstream of rock sill

Detached Breakwater Toe Protection Design

In the 1996 toe protection design, only 46 lineal meters of the 136 lineal meters of breakwater downstream of the rock sill was to receive new toe protection. Results from the model study with sill in place (but with no toe protection) indicated that the unprotected 92 lineal meters of breakwater would be vulnerable to scour-related damage under the 1996 toe protection design. Costly future repairs could be avoided if the toe protection was extended over the entire 136 m of breakwater. It was also felt that the 1996 design cross section was overly conservative, and cost savings could be realized by optimizing the design using the physical model. Three toe berm alternatives were examined in the movable-bed model, and each design improved on the previous alternative.

Plan 1 featured a 7.6-m-wide berm constructed of quarry-run material with highest elevation at -2.8 m MLLW. As scour occurred downstream of the rock sill, a significant portion of the berm bench slumped into the scour hole that developed in the model. The remaining berm was stable under both currents and combined wave/current action. One worrisome aspect of Plan 1 (and the 1996 design) was the need to excavate to a depth below the toe of the existing armor slope to place the new toe berm. During excavation there would be a risk of initiating a slope failure, resulting in costly repairs and project delay.

Plan 2 was designed with a 1-m-thick layer of larger stone over a 1-m-thick layer of quarrystone. This plan featured a 3-m-wide horizontal bench at the -1.0-m elevation and a sloping berm having a 14.3-m horizontal extent. Although a portion of the sloping berm was undermined during the test, Plan 2 provided plenty of reserve protection. However, after completion of the test it was realized that the berm elevation of Plan 2 was significantly higher than the -4.5-m MLLW elevation of the rock sill. This would prevent larger dredges from accessing the sand trap to the north of the north jetty, as well as being a serious navigation hazard for smaller vessels. Potential costs associated with dredge and vessel grounding, and possibly the need to remove the berm at some later date, made Plan 2 much less desirable than originally thought.

The potential problem of Plan 2 was alleviated by the Plan 3 design shown in the upper portion of Figure 6. This berm was composed of only quarry-run stone and featured an 11.6-m-wide by 3-m-thick horizontal bench at an elevation of -4 m MLLW. Risk to the existing breakwater toe was lessened by excavating on a slope as illustrated in the figure. Plan 3 proved to be fully adequate as indicated by the lower sketch of Figure 6.

Study Benefits

The Ventura Harbor model study was completed successfully, and the following benefits were realized as a direct result of the study:

- The model study confirmed that scour would indeed undermine the detached breakwater toe, which would result in extensive damage to the leeside armor layer. Thus, the proposed toe reinforcement was shown to be necessary.
- The study showed that the entire 136 linear meters of breakwater toe downstream of the sill needed to be protected from scour. The 1996 design would

have left 92 lineal meters exposed to scour-induced slope failure.

- The physical model was used to optimize the toe apron cross-section design and to demonstrate that the optimized design was stable with sufficient residual protection. The final design cross section used 25 percent less stone than the 1996 design, and the new design prevented an estimated $475,000 in additional breakwater damage that might have occurred in the absence of adequate toe scour protection.
- While working in the physical model, it was realized that the original 1996 toe protection design and the Plan 2 design (which was out for bid) were to be constructed at an elevation that would hinder passage of the dredge through the gap between the detached breakwater and the north jetty spur. The final design corrected this error, thus avoiding potential costs related to grounding of the dredge and subsequent rebuilding of the toe protection to correct the problem.
- The 1996 toe protection design called for excavation that involved a risk of leeside armor layer instability, whereas the final design is easier to construct with less risk to the existing structure. Thus, construction costs were likely reduced, and the potential for costly damage during construction was also decreased.
- Finally, this laboratory study showcased the positive interaction between field engineers and laboratory personnel fostered under the *Coastal Engineering Education Program.*

The Ventura Harbor Entrance project has evolved significantly from the time of original construction as engineers worked to correct unforeseen consequences of their work. Given the complexity of nearshore hydrodynamic and littoral processes, well-functioning man-made harbor entrances should be considered tributes to those engineers who persisted and learned from nature what modifications were required.

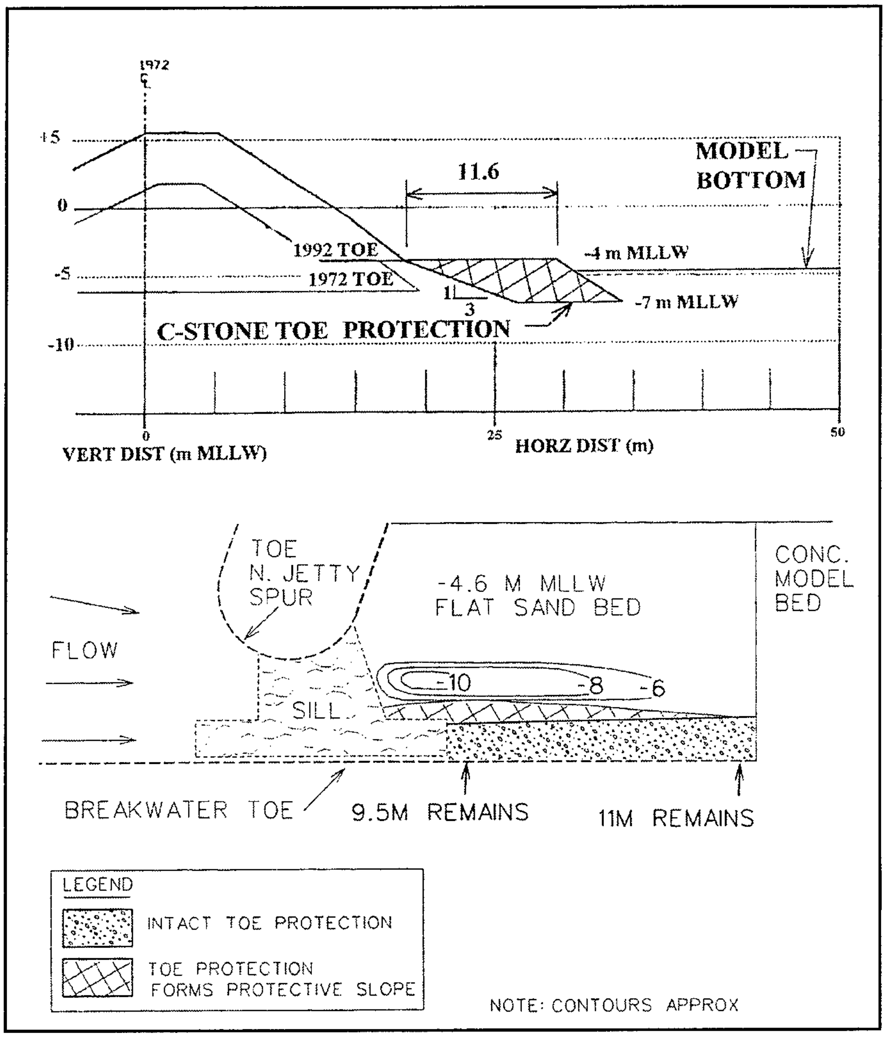

Figure 6. Detached breakwater toe protection: Plan 3

Acknowledgements

The research described and the results presented herein were obtained from research conducted under the *Scour Holes at Inlet Structures* work unit in the *Coastal Inlets Research Program* at WES. Mr. Raymond Reed, Mr. Willie Dubose, and Mr. Ernest Smith of WES are acknowledged for their contributions to the laboratory experiments. Mr. Arthur Shak, Los Angeles District, made valuable suggestions on the toe protection design.

Postscript: Effects of January 1998 storms

Armor layer repairs and leeside toe protection for the Ventura Harbor detached breakwater were completed in late 1997. To date, three winter storms producing wave heights H_s of 5.7 m, 6.2 m, and 5.7 m with significant periods of 15 to 20 sec were recorded in deep water at Harvest Platform. The waves generated by these storms were similar in magnitude to those that caused the original scour and damage to the Ventura breakwater in 1995.

During the 30 January 1998 storm, a rip current was observed flowing along the Ventura Harbor north jetty and accelerating through the gap. The current pulsated in strength, with maximum velocity immediately after the arrival of a group of waves. A maximum current velocity of 1.5 m/sec was estimated along the north jetty by timing the flow of debris over a known distance. Similarly, reference marks painted on the recently repaired

detached breakwater were used to estimate maximum velocities near 7 m/sec through the gap between the north jetty spur and breakwater.

The breakwater leeside armor layer had three areas of minor damage located upstream of the recently completed toe protection. It is assumed that the damage was caused by wave overtopping. No scour-related damage to the leeside armor layer downstream of the gap was observed.

Results from the model study had predicted that the toe protection was necessary to prevent breakwater damage during storm conditions such as those that occurred during January 1998. It appears that the toe protection is functioning as intended, and significant losses due to damage have been avoided at the Ventura Harbor navigation project.

Coastal Sediments '99

The U.S. Army Engineer Waterways Experiment Station (WES) is a co-sponsor of COASTAL SEDIMENTS '99, the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes, to take place 20-24 June 1999 on Long Island, New York, USA. The conference theme is "Scales of Coastal Sediment Motion and Geomorphic Change." Short courses will be held 20 June, and technical tours will be conducted 24 June.

COASTAL SEDIMENTS '99 is a multi-disciplinary international conference convened for researchers and practitioners to discuss science and engineering issues of coastal sediment processes. The conference will provide a high-level technical forum for exchange of information among engineers and scientists in the fields of coastal engineering, geology, and oceanography. The theme of the conference was chosen to stimulate research and development of papers treating the various temporal and spatial scales at which coastal scientists and engineers must work. The theme is intended to promote discussion and understanding of coastal sediment processes from micro-scale turbulence to the regional scale at which integrated coastal design should be implemented.

Prospective authors are invited to submit five copies of an abstract by 11 May 1998 for papers on the following and related session topics:

- **Session 1: Coastal Sediment-Transport Processes** (theory and measurement, longshore transport, cross-shore transport, sediment transport at inlets, cohesive sediment transport).
- **Session 2: Coastal Engineering Applications** (sediment budgets, impacts of inlets on the coast, impacts of dams on the coast, numerical and physical modeling, beach nourishment, performance of erosion-control structures, sand bypassing and dredged material use, shoaling and migration, GIS and remote sensing for coastal analyses, field data collection and laboratory measurements).
- **Session 3: Coastal Geomorphic Processes** (large-scale coastal evolution, barrier island sedimentation processes, inlet evolution, shoreline and beach profile change, storm impacts).

Total length of the abstract should not exceed two pages, including figures. Abstracts must have a title and give the affiliation and mailing address of the author(s), as well as an e-mail address, telephone, and facsimile number for the corresponding author. Please indicate in the upper right-hand corner of the first page the session number and/or session topic, to aid the technical review committee in identifying the most appropriate session for presentation. An individual may not be the first author or the presenter of more than one paper. Abstracts should be sent by postal or courier service (no e-mail) to Professor William G. McDougal, Co-Chair, COASTAL SEDIMENTS '99, Department of Civil Engineering, Oregon State University, Corvallis, OR 97331-2302. Dr. Nicholas C. Kraus, WES Coastal and Hydraulics Laboratory, is serving as Conference Co-Chair. Notification of abstract acceptance will be made by 14 September 1998, with submission of full papers required by 15 February 1999. Submission of the final manuscript implies a firm commitment to present the paper.

Five short courses will be offered 20 June on the following subjects:

- Modern Coastal Zone Surveying Techniques and Applications
- Properties and Analysis of Beach Shoreline and Profile Change, with Engineering Applications
- Geomorphology, Dynamics, and Engineering of Tidal Inlets
- Video Imaging Techniques and Applications in the Nearshore
- Mechanics of Coastal Sediment-Transport Processes

Technical field trips of the New York and New Jersey coastlines will be conducted 24 June. Short courses and field trips will be available optionally at minimal cost to participants.

For the latest information on the conference, including a list of accepted abstracts by sessions, electronic registration, and hotel and transportation information, access the conference web site at http://www.coastalsediments.org

Effects of Inlet Modifications at Barnegat Inlet, New Jersey

by William C. Seabergh[1], Mary A. Cialone[1], and John W. McCormick[2]

Introduction

After completion in 1991 of a new south jetty at Barnegat Inlet, New Jersey (Figure 1), the U.S. Army Corps of Engineers began collection of a large data set in 1993 to evaluate the hydraulic performance of this project. Both historical and present-day hydraulics of Barnegat Inlet were examined. Long-term (34 days) and short-term (13 and 25 hr) velocity measurements were made with Acoustic Doppler Current Profilers (ADCPs). Tides were measured at five locations in Barnegat Bay, and waves were measured for 1 year. Wind measurements were available for the duration of the study. Present-day tidal prisms were computed, and the effects of the project on bay tide range and inlet entrance channel velocity distribution were examined. Using the long-term velocity record in the entrance channel, variations in tidal prism, flow predominance, flood/ebb duration and phase lag, fortnightly bay setup, potential net sediment transport, and wind effects on bay tide elevations were determined.

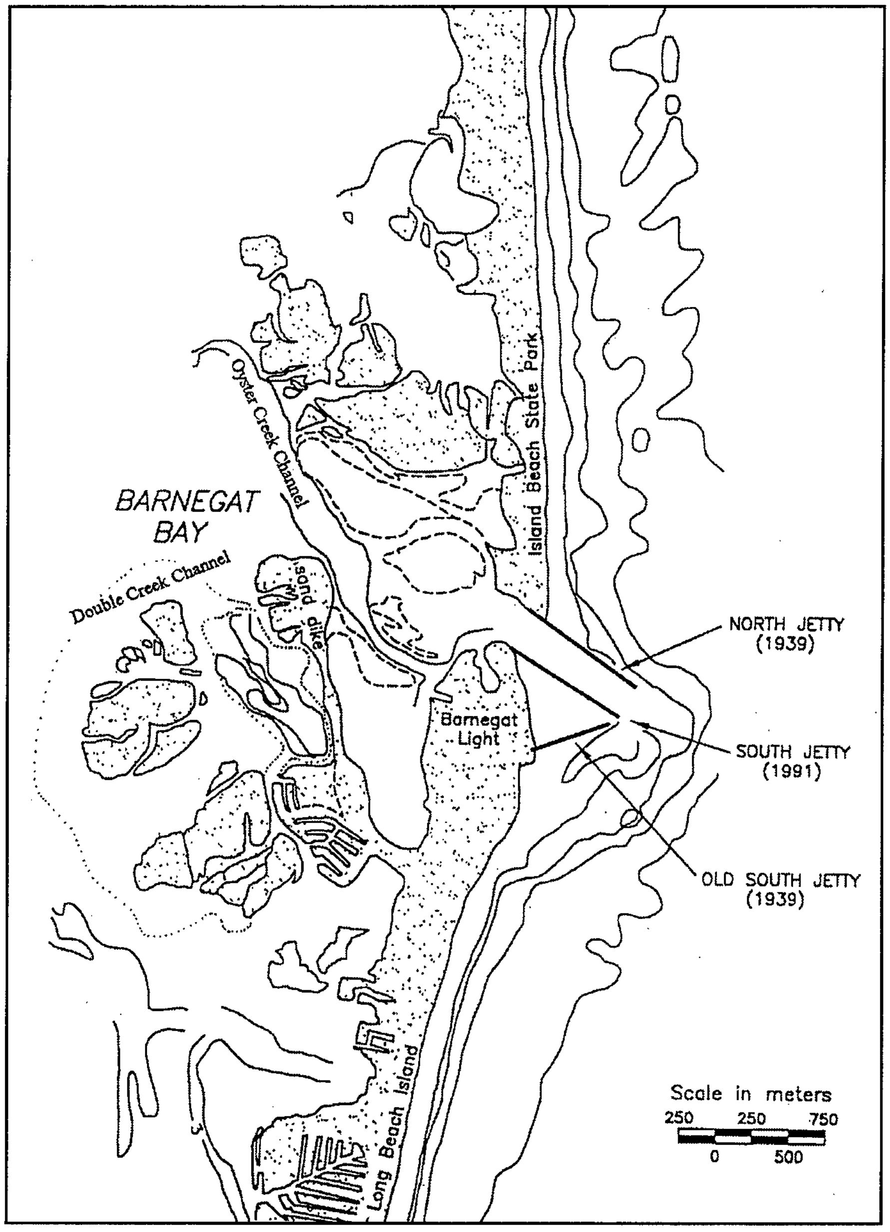

Figure 1. Location map, Barnegat Inlet, New Jersey

Background

Barnegat Inlet is a stabilized inlet located on the New Jersey coast, approximately 90 km (50 miles) south of Sandy Hook and 125 km (70 miles) northeast of Cape May. The inlet separates Island Beach State Park (to the north) from Long Beach Island (to the south) and serves as the primary link between the Atlantic Ocean and Barnegat Bay. The surface area of Barnegat Bay is approximately 124 km^2

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(48 sq miles). The ebb tidal delta is asymmetrically skewed to the south (in the direction of predominant littoral drift). A double flood shoal and meandering navigation channel are present within a large relict flood tidal delta on the bay side of the inlet. The barrier island south of Barnegat Inlet is heavily structured with 110 groins.

Early shoreline maps dating back to 1839 indicate that the inlet has migrated to the south, initially at a rate of 12 m/year (40 ft/yr) from 1839 to 1866, then slowing to a rate of 6 m/year (20 ft/year) from 1866 to 1932 (Caccese and Spies 1977). The continued southward migration of the inlet was prevented by the construction of two converging (arrowhead) rubble-mound jetties in 1939-1940 as part of a Federal navigation project. As constructed, the north jetty was 1,484 m (4,900 ft) long and the south jetty was 899 m (2,950 ft) long. Jetty elevations were +2.4 m (8 ft) above mean low water (mlw) at the landward end and sloped to +0.6 m (2 ft) mlw at the shoreline and continued at this elevation to the seaward end. With an ocean mean tide range of 1.3 m (4.2 ft), there was tidal flow over the jetties when water elevation was above mean tide level. The jetties were 1,067 m (3,500 ft) apart at the landward end and were spaced much closer together (305 m (1,000 ft)) at the seaward end. The arrowhead configuration was selected to provide flow convergence, promoting scour to maintain the desired channel depth in the inlet throat.

In response to the channel stability problem, hydraulic model studies were conducted at WES (1968-1974) to develop a recommended plan of improvement with respect to maintaining an effective navigation channel (Sager and Hollyfield 1974). The model study concluded that the construction of a new south jetty parallel to the existing north jetty and a 91-m- (300-ft-) wide, 3-m- (10-ft-) deep channel would provide inlet and channel stability. The jetty would extend from an existing groin at the base of the Barnegat Lighthouse to the tip of the existing south jetty.

The new 1,302-m- (4,270-ft-) long, impermeable south jetty was constructed to an elevation of 2.4 m (8 ft) mlw between December 1987 and June 1991 and was nearly parallel to the north jetty (U.S. Army Corps of Engineers 1984). The old south jetty was not removed upon completion of the new south jetty, but the region between the two was filled with sediment excavated for the new south jetty's foundation. Initial dredging of the navigation channel was completed in early 1992. It is the performance of this project that is being monitored and evaluated.

Monitoring Program

As part of the Monitoring Completed Navigation Projects (MCNP) studies at the U.S. Army Engineer Waterways Experiment Station (WES), Coastal and Hydraulics Laboratory (CHL), field data were collected to evaluate the design parameters and project performance of the new south jetty and navigation channel at Barnegat Inlet, New Jersey. The goal of the MCNP program is to gather and analyze data to (a) develop an improved understanding of the physical processes at a project site, (b) evaluate the performance of the project, and (c) enhance future design procedures. Data collected included tide and wave measurements, currents in the inlet throat and near the flood shoal, time-lapse video photography of the channel and flood shoal, aerial photography, bathymetric surveys, beach and offshore profiles, and structural inspections of the new south jetty. In addition, a Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) of the entire Barnegat Inlet system was conducted in July 1994.

Nearly continuous tidal records for five locations in Barnegat Bay were analyzed to determine changes in tidal constituents and bay tide range since completion of the project. The effects of wind on Barnegat Bay tide elevations were also examined. Short-term (13- and 25-hr duration) measurements of tidal current in the inlet throat and near the flood shoal were used to determine flow patterns. A longer-term (34-day) tidal current data collection effort at a single point in the inlet throat was conducted and correlated with short-term measurements to understand variations in discharge and tidal prism over a lunar month. The tidal prism was compared historically to the tidal prism computed from the present data collection effort. In addition, the effect of lunar tide variation on ebb and flood flow duration and phase lags was examined.

Summary of Monitoring Conclusions

Barnegat Inlet has a small bay tide range (0.1-0.2 m (0.3-0.7 ft)) relative to the mean ocean tide (1.3 m (4.25 ft)). This is due to the large bay size in comparison to the inlet's cross-sectional area in the throat, leading to interesting asymmetries in flood and ebb flows. Maximum flood flow in the entrance channel occurs near ocean high-water elevations and maximum ebb flow occurs near ocean low-water elevations. Descriptively, the bay tide elevation is a relatively constant plane while the ocean tide oscillates about that plane, with maximum head differences between ocean and bay near ocean high and low water.

Flood Flow Predominance

Maximum flood flow occurs at high water; maximum ebb flow occurs at low water. Friction increases for ebb flow moving through a smaller, shallower cross-sectional area. Because of this, ebb flow is longer in duration than flood flow. This effect is magnified during spring tide conditions relative to neap for two reasons. First, the spring low water elevation is lower, which limits ebb flow to a larger degree. Second, spring high water is higher, enhancing greater flood flow. Friction is enough to attenuate ebb velocity more than flood for spring tide conditions, so that there is strong flood current predominance.

The friction effect creates a limiting value of about 1,400 m^3/sec for maximum ebb discharge. In contrast, maximum flood flow discharges are as much as 60 percent higher than maximum ebb flow discharges and much more variable. As neap tide ranges are approached, ebb flow predominates as flood flow falls below the ebb threshold. Water stored in the bay during spring tides is gradually released to the ocean during the transition from spring to neap tide, also contributing to ebb predominance at neap tides. Flood flow predominates during spring tides accompanied by inability to fully drain during ebb flow (due to the maximum discharge capacity of the channel). This creates a net storage in the bay until the transition from spring to neap tide occurs, when there is a net outflow. Ebb flow typically reaches its maximum duration during spring tide, as the increased super-elevation of the bay creates a bay-to-ocean elevation gradient greater than during neap tides for a greater portion of the tidal cycle.

Tidal constituents at the Coast Guard Station, just inside the jetty system, indicate an increase in flood dominance and greater admittance into Barnegat Bay since completion of the new south jetty, as compared to the arrowhead jetty configuration. This is due to an increase in minimum cross-sectional area in the jetty region and channel straightening and deepening. However, when the new jetty configuration is compared to the pre-stabilized inlet tides (1932), bay tide ranges for the present conditions are very similar (range of 0.13 to 0.17 m (0.4 to 0.6 ft)). Bay tide range decreased when the arrowhead (mean tide level crest elevation) jetties were constructed, then increased from arrowhead to present-day configuration. An FFT of the bay tide indicates that the strongest periodicity occurs monthly, in phase with the largest monthly maximum spring tide. Secondary spring tide energy (14.5-day periodicity) is nearly equal in magnitude to the bay's semidiurnal tide energy.

Wind Effects

Wind can change the typical trends for ebb/flood flow duration and net bay inflow/outflow. Winds along the channel axis can enhance bay inflows/outflows. Winds from the southeast and east enhance flood tidal prism and extend duration. Winds from the south can enhance ebb tidal prism and duration, possibly introducing some water from the south (through the intracoastal waterway and surrounding marshy regions). However, winds from the south can also minimize ebb tidal prism if the tidal phasing and southerly wind duration are such that northerly bay setup and wind stress on the bay impede ebb flow. Winds from the northwest increase ebb tidal prism. The effects of winds on the bay tide elevations can also be significant, especially when considering that the average bay tide range is only 0.12 m (0.4 ft). When winds are from the south and southwest, the northern portion of Barnegat Bay was superelevated by as much as 0.40 m (1.3 ft). Winds from the north, northeast, and northwest reverse the head difference, elevating the southern portion of Barnegat Bay up to 0.24 m (0.8 ft)).

Tidal Velocities

Three transect locations for tidal velocity measurements traversed the main channel (Figure 2). Short-term ADCP data collection and analysis showed that the distributions of velocities are consistent for mean and spring conditions (Figure 3). Approximately two thirds (64-71 percent) of the ebb flow exited through the interior navigation channel and one third (29-36 percent) exited over the flood shoal. Flood flow entering into the bay for mean tide conditions indicated about 56 percent of the flow over the flood shoal region and 44 percent moving through the interior navigation channel adjacent to the lighthouse. This compares with 65 percent over the flood shoal and 35 percent through the channel for spring tide flood flow conditions. Flood flows at the seaward end of the inlet (Transect C)

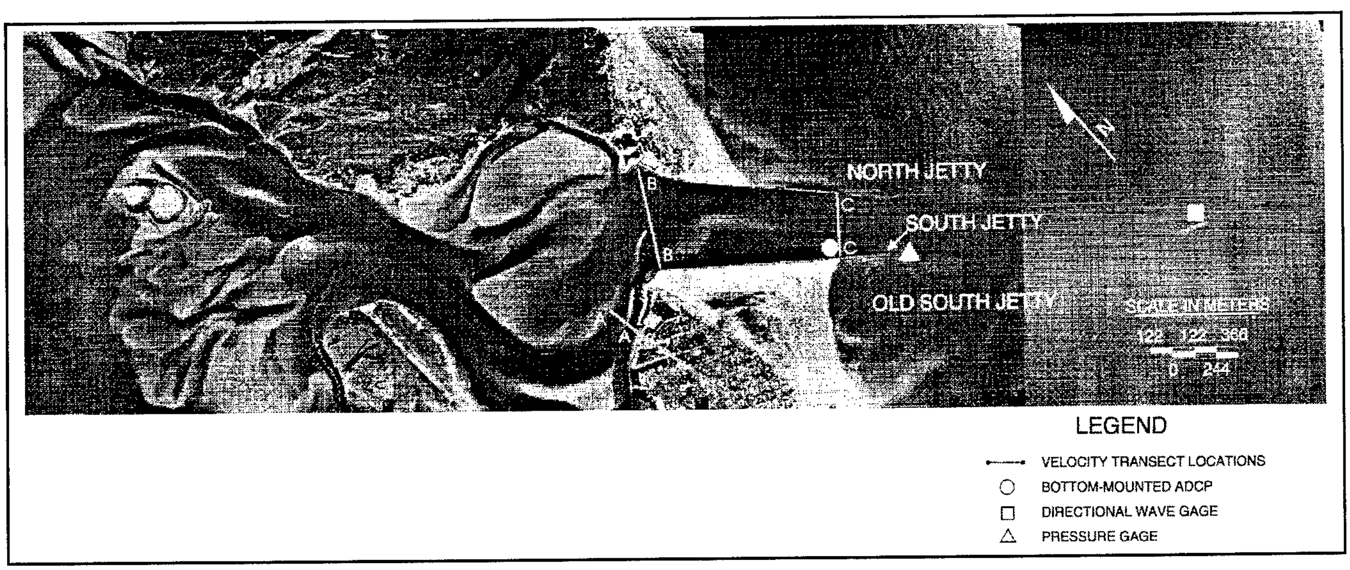


Figure 2. Barnegat Inlet transects and instrumentation location

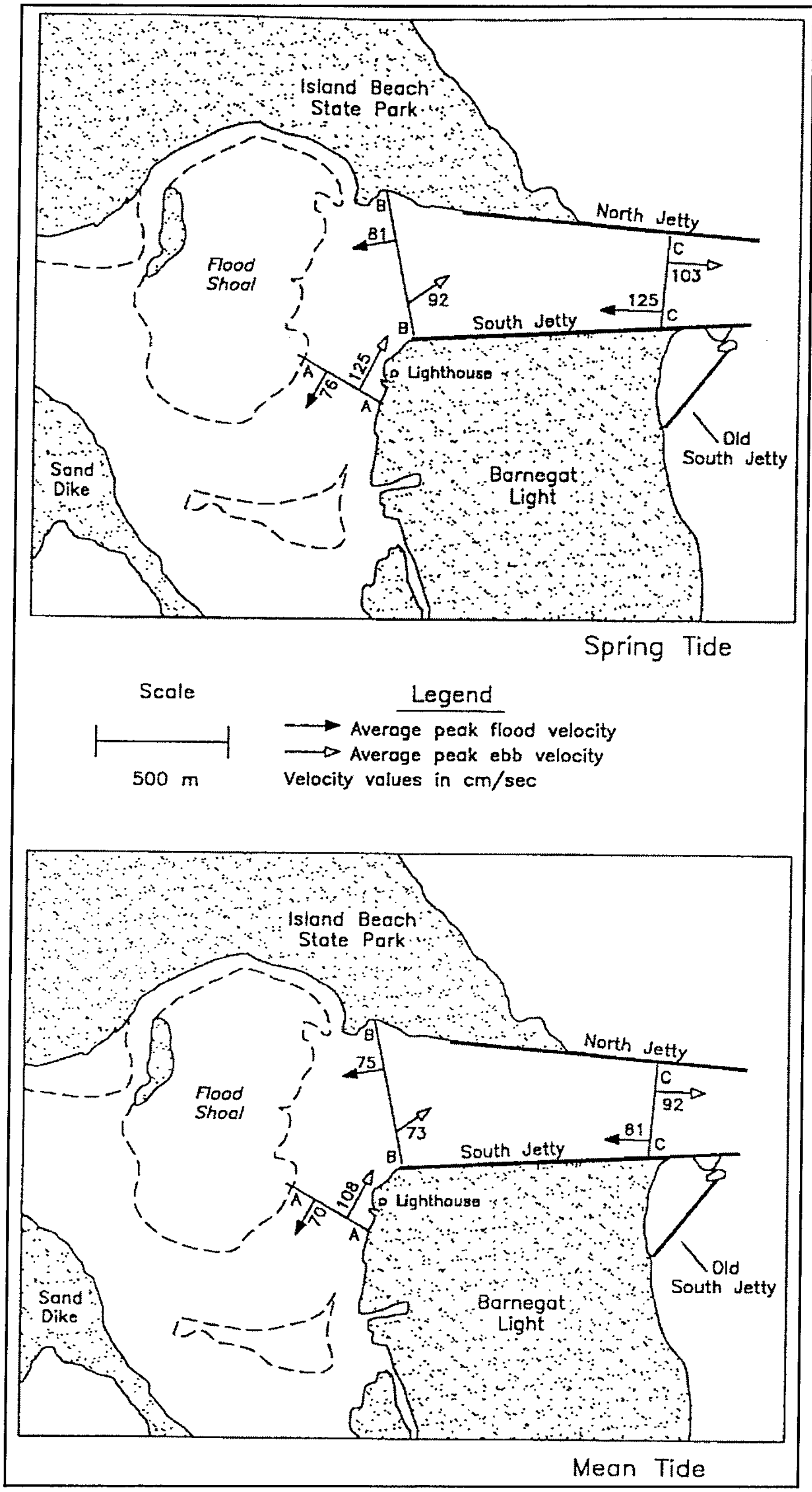


Figure 3. Average peak flood and ebb velocities at Transects A, B, and C for spring and mean tide conditions

are strongest near the south jetty. Flood velocities near the inner part of the intra-jetty area (base of the lighthouse, Transect B) are strongest on the north side of the inlet. Flood velocities at Transect A are strongest close to the flood shoal. This trend shows that flood velocities follow the navigation channel. On ebb, the trends are reversed, with the southern side of Transects A and B and the northern side of Transect C having the stronger ebb velocities.

For spring tide conditions, Transect C has higher average peak flood velocities (indicating local flood dominance) and Transect B has higher average peak ebb velocities (indicating local ebb dominance). Overall mean conditions are nearly balanced, with a slight ebb dominance. The strong flood dominance at Transect C for spring tide conditions indicates the potential for sediment movement into the intra-jetty region. However, Transect B showed ebb dominance, also indicating the potential for sediment movement into the intra-jetty region. These findings support shoal development in the intra-jetty region. The strong spring tidal flood dominance indicates that Barnegat Inlet is a flood-dominated inlet.

Analysis of the 34-day bottom-mounted ADCP data showed that the lower magnitude ebb velocities are more uniform over depth (linear distribution), whereas the higher flood velocities have a logarithmic distribution over the same depth range. Flood tide conditions resulted in significantly larger average velocities (0.3 m/sec (1.0 ft/sec) greater). Flood and ebb velocities are directed somewhat towards the south jetty due to structural and bathymetric controls. The weir section at the oceanward end of the north jetty and greater adjacent seaward depths relative to the south approach to the inlet help direct flood flow to the south side of the intra-jetty region. Ebb currents entering the intra-jetty region from the bay, once past the intra-jetty shoal, expand into the deeper water seaward of the shoal and are somewhat directed toward the south jetty.

During spring tide, where flood velocities greatly exceed ebb velocities, flood dominance of potential sediment transport is implied. During neap conditions, where flows are more nearly in balance, sediment transport magnitude estimates were more evenly distributed and net transport is slightly ebb-dominated due to longer ebb durations. Analysis of the entire 34-day record indicates that the cumulative sediment transport potential is flood-dominated.

Tidal Prisms

Tidal prisms based on velocity measurements indicated that the inlet has returned to prism magnitudes measured in the 1930's and early project years of the 1940's. Detailed, short-term ADCP measurements indicate spring tide prisms ranging up to 32.4×10^6 m^3 (11.4×10^8 ft^3). Early 1940's measurements were as high as 34.5×10^6 m^3 (12.2×10^8 ft^3). This agreement follows naturally from the similarity between the 1930's and 1990's bay tide range measurements. In contrast, late 1960's to 1980's prisms measured $10.9\text{-}13.9 \times 10^6$ m^3 ($3.8\text{-}4.8 \times 10^8$ ft^3) when the inlet was more choked. This change in prism is accounted for by a 40-percent increase in minimum channel cross-sectional area for the new project. In addition, the oceanward side of the inlet gorge between the jetties is much deeper for the high parallel jetty system than for the low elevation arrowhead jetty system of the 1960s to 1980s.

The 34-day tidal prism data, derived from an ADCP moored on the channel bottom in an upward-facing direction, indicate that a fairly wide range of tidal prism magnitudes can occur, depending on tide range and wind conditions. Ebb tidal prisms varied between 12.5 and 33.0×10^6 m^3 (4.4 and 11.7×10^8 ft^3) and flood prisms varied between 8.9 and 41.3×10^6 m^3 (3.1 and 14.6×10^8 ft^3). Wind conditions were a factor in all the extreme cases. Strong winds along the channel axis (northwest and southwest) contributed to maximum extremes in tidal prism. Strong southerly winds along the longitudinal bay axis existed for each minimum tidal prism.

References

Caccese, L. A., and Spies, H. R. (1977). "Barnegat Inlet, nature prevails." *Proceedings, Coastal Sediments '77.* American Society of Civil Engineers, 305-310.

Sager, R. A., and Hollyfield, N. W. (1974). "Navigation channel improvements, Barnegat Inlet, New Jersey, hydraulic model investigation," Technical Report H-74-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Army Corps of Engineers. (1984). "Barnegat Inlet, Ocean County, New Jersey, Phase II General Design Memorandum," U.S. Army Engineer District, Philadelphia, PA.

Coastal Engineering Courses Scheduled

Two coastal engineering courses have been scheduled as part of the Corps of Engineers PROponent SPonsored Engineering Course Training (PROSPECT) program. The first course (**Fundamentals of Coastal Engineering**), to be held 27-31 October 1998 at the WES Coastal and Hydraulics Laboratory (CHL), provides an overview of basic coastal engineering. The second course (**Coastal Engineering Practices, Projects, and Designs**), to be held 2-6 November 1998 also at the WES CHL, covers detailed design procedures required for many coastal projects. The two courses are offered during consecutive weeks to minimize travel costs.

Fundamentals of Coastal Engineering will include an introduction to coastal engineering, introduction to the Automated Coastal Engineering System (ACES), coastal waves, linear wave theory, wave refraction and diffraction, wave hindcast and forecast, longshore sediment transport, cross-shore sediment transport and beach profile change, introduction to coastal geomorphology, tidal inlets and channel stability, hydrodynamics and shoaling, sand bypassing at inlets, design wave and water level, protective measures against waves, laboratory simulation of waves, Coastal Modeling System (CMS), and field data collection and databases.

Coastal Engineering Practices, Projects, and Design will include coastal structures, applications of ACES, wave runup and overtopping, wave transmission and reflection, scour and toe protection, inlet jetties and impacts on beaches, design of seawalls and bulkheads, design of revetments, impacts of seawalls and revetments on beaches, detached breakwaters and groins, dredging fundamentals, beach fill design and performance predictions, beneficial uses of dredged material, offshore berms, rubble-mound structures, armor unit design, physical modeling of harbors, physical modeling of coastal structures, nearshore survey technology, and coastal construction materials.

Registration for these coastal engineering courses will begin on 15 April 1998 and continue through 15 June 1998. Point of contact is James Clausner (601)634-2009, e-mail j.clausner@cerc.wes.army.mil.

USACE is Co-Sponsor of National Symposium on Contaminated Sediments

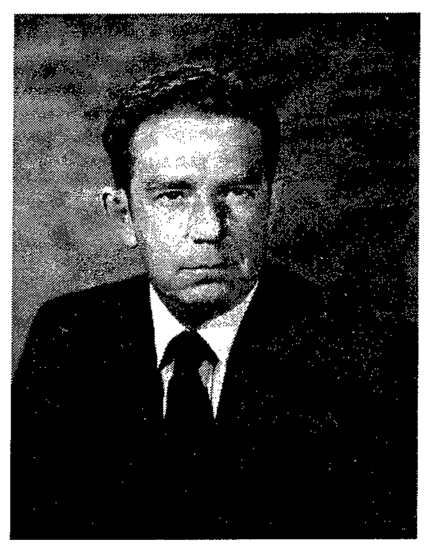
The U.S. Army Corps of Engineers (USACE) is a co-sponsor of the **National Symposium on Contaminated Sediments: Coupling Risk Reduction with Sustainable Management and Reuse**, to be hosted by the Transportation Research Board of the National Research Council (NRC). The symposium will be held at the National Academy of Sciences Building in Washington DC on 27-29 May 1998. A major feature of the symposium will be discussion of issues addressed in the NRC report "Contaminated Sediments in Ports and Waterways: Cleanup Strategies and Technologies," published in March 1997. The program will include stakeholder responses to the study report, case study presentations, perspectives on project implementation, examination of technologies and ongoing research and development, and an industry roundtable. There will be poster displays and exhibits which highlight a broad range of strategies and technologies. There also will be an optional field visit to the Maryland Port Administration's Hart Miller Island Dredged Material Containment Facility (limited space available). For information and registration materials, contact Joedy Cambridge, phone (202) 334-2167, fax (202) 334-2030, e-mail jcambridg@nas.edu. The USACE liaison to the symposium steering committee is Joseph Wilson, program monitor of the 8-year $48-million Dredging Operations and Environmental Research (DOER) program being conducted by the U.S. Army Engineer Waterways Experiment Station (WES).

Congressman Nick Lampson Visits WES

Congressman Nick Lampson, D-Texas, 9th Congressional District, recently visited the WES Coastal and Hydraulics Laboratory. Congressman Lampson's district covers the coastal areas of Galveston and Jefferson Counties, Texas, portions of which are experiencing chronic erosion which has damaged coastal Highway 87. While at WES, Congressman Lampson received briefings from researchers involved with coastal inlets, shore protection, dredging, and related issues. He also toured laboratory facilities and several physical model studies, including the movable-bed idealized inlet model of the Coastal Inlets Research Program. Congressman Lampson took the opportunity to discuss site-specific coastal issues of his district with the WES technical staff.

Richard A. Sager Retires

Richard A. (Dick) Sager, former Assistant Director of the WES Coastal and Hydraulics Laboratory (CHL), retired on 3 January 1998 after more than 41 years of distinguished federal service. After receiving a degree in civil engineering from the University of Colorado in 1956, he was employed for a year with the U.S. Bureau of Reclamation before entering military service in 1957. He was stationed as an enlisted man in the Special Investigations Section of the WES Hydraulics Laboratory (HL) until leaving military service in 1959. He remained at WES as a civil engineer in the Nuclear Weapons Effects Division of the Structures Laboratory (SL) until 1964 when he was selected Chief, Material Section, SL. In 1965 Dick transferred back to the HL. Here he rose through the ranks from the position of hydraulic engineer to Chief, Coastal Section, to Chief, Estuaries Division, and then to Assistant Director, HL (later Assistant Director, CHL, when CHL was created by the merger of HL and the Coastal Engineering Research Center). Dick received numerous awards for the tremendous ccontributions he made throughout his career. We wish Dick the very best in his retirement.



Louisiana Oil Spill Research Symposium '98
6 May 1998

The Louisiana Oil Spill Coordinator's Office/Office of the Governor, in conjunction with the Louisiana Applied Oil Spill Research and Development Program (OSRADP), will host a 1-day symposium on Louisiana-sponsored oil spill research. The Research Symposium will showcase a "spill of opportunity" plus 10 research projects, including undocumented and abandoned pipelines, phytoremediation for oil spill cleanup, engineered application of bioremediation to oil spills in coastal wetlands, interaction between oil spills and fresh marsh types, effects of crude oil on microbial functions, oil spill in Lake Barre, the Oil Spill Contingency Plan Map CD, and others. The symposium is designed to provide a forum for the exchange of ideas and allow the scientists funded through OSRADP an opportunity to highlight the scientific, technical, and economic aspects of individual research. Symposium presenters include a broad cross section of researchers, including scientists, engineers, planners, and policy makers, who will develop a meaningful dialogue on the multifaceted nature of the oil spill business.

The symposium will be held at Louisiana State University, Pennington Biomedical Research Center, Pennington Conference Center, 6400 Perkins Road, Baton Rouge, Louisiana. Additional information is available from The Louisiana Applied Oil Spill Research and Development Program, Oil Spill Research Symposium '98, E302 Howe-Russell Geoscience Complex, Baton Rouge, Louisiana 70803, phone 504-388-3481/3477, fax 504-388-0403, e-mail osradp@ ibm.net

Calendar of Coastal Events

Apr 6–10, 1998	**National Hurricane Conference: 20th Annual Meeting,** Norfolk, VA, USA, POC: National Hurricane Conference, 2952 Wellington Circle, Tallahassee, FL 32308, phone (850) 906-9224, fax (850) 906-9228
Apr 8–10, 1998	**SECOR, Conference on Southeast Coastal Ocean Research,** Savannah, GA, USA, POC: Merryl Alber, Conference Chair, University of Georgia, School of Marine Programs, Department of Marine Sciences, Athens, GA 30602-2206, phone (706) 542-7671, fax (706) 542-5888, e-mail malber@uga.cc.uga.edu
Apr 13–17, 1998	**Fifteenth International Sedimentological Congress,** Alicante, Spain, POC: Departamento de Ciencias de la Tierray Medio Ambiente, Facultad de Ciencias, Campus de San Vicente de Raspeig, Universidad de Alicante, Apartado 99.03080 Alicente, Spain
Apr 30 – May 1, 1998	**1998 International Symposium on Ocean Wave Kinematics: Dynamics and Loads on Structures,** Houston, TX, USA, POC: Dr. Zeki Demirbilek, phone (601) 634-2834, e-mail z.demirbilek@cerc.wes.army.mil; Dr. Robert E. Randall, e-mail r-randall@tamu.edu
May 7–9, 1998	**First Annual Conference of the Northeast Chapter, American Shore and Beach Preservation Association,** "Local Efforts in Shoreline Management and Protection," Ocean City, New Jersey, USA, POCs: Dr. Richard Weggel, phone (215) 576-6307; Dr. Robert Sorensen, phone (610) 758-3556
May 19–23, 1998	**International Coastal Symposium,** Palm Beach, FL, USA, POC: ICS-98 Secretariat, P.O. Box 210187, Royal Palm Beach, FL 33421; Challis Briethaupt, Conference Coordinator, P.O. Box 1897, Lawrence, KN 66044-8897, phone (800) 627-0629 or (913) 843-1221, fax (913) 843-1274, e-mail am&m@allenpress.com
May 25–29, 1998	**Education and Training in Coastal Management: The Mediterranean Prospect,** Genoa, Italy, POCs: Darius Bartlett, Department of Geography, University College Cork, Ireland, phone (+353) 21 902835, fax (+353) 21 271980, e-mail DJB@UCC.IE; Adalberto Vallega, Scientific Coordinator, phone 39-10-209.5858, fax 39-10-209.5907, e-mail vallega@polis.unige.it; Secretariats: Stefano Belfiore, Francesca Borneto, Ombrina Pistarino, phone/fax 39-10-209.5840, e-mail iccops@polis.unige.it
Jun 16–20, 1998	**PACON '98: Eighth Pacific Congress on Marine Science and Technology,** Seoul, Korea, POCs: Narendra Saxena, Hawaii, fax (808) 956-2580; Kenji Hotta, Japan, fax 81-47-467-9446; David Hopley, Australia, fax 61-77-755-429; Wang Ying, China, fax 86-25-330-6387; Hyung Huh, Korea, fax 82-345-408-5934

US Army Corps of Engineers
Waterways Experiment Station

The Corps' Coastal Vision Statement

We will, as the National Coastal Engineer:

- **Continue our leadership in the protection, optimization, and enhancement of the Nation's coastal zone resources.**
- **Increase our contribution to the Nation's economy, quality of life, public safety, and environmental stewardship.**

The CERCular

Coastal Engineering Research Center

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http://bigfoot.cerc.wes.army.mil/CERC_homepage.html

Contributions of pertinent information are solicited from all sources and will be considered for publication. Communications are welcomed and should be addressed to the U.S. Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory, ATTN: Dr. Lyndell Z. Hales, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call (601) 634-3207, FAX (601) 634-4253, Internet: l.hales@cerc.wes.army.mil

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